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# DOUGLAS-FIR CONE AND SEED INSECT RESEARCH

Progress Report, 1960

By

Thomas W. Koerber, Entomologist

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Division of Forest Insect Research

# DOUGLAS-FIR CONE AND SEED INSECT RESEARCH

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## SUMMARY

This is a report on the progress of studies on the insects which destroy the seeds of Douglas-fir. The purpose of these studies was to obtain information on the identity, habits, and life cycles of these insects. The data obtained will serve as the basic background for the development of methods to control these pests.

Among the insects found in association with the Douglas-fir cones were seven species which have not previously been reported in this connection. Three of these are species which are potentially harmful to the cones or seeds. The remainder are parasites of insects known to destroy Douglas-fir seeds.

Studies in which infested cones were held under observation from 1959 through 1961 revealed that a substantial portion of the populations of two of the most important seed-destroying insects delay transformation to the adult stage for at least 1 year. That is, some of the larvae which infested cones of the 1959 crop did not emerge as adults until the spring of 1961. This habit permits substantial numbers of insects to survive in years when the cone crop fails. Five species of parasites and predators were also found to delay their transformation to adults.

Studies on the seasonal history and habits of the insects revealed that all of the species attack the cones during April and May except Dioryctria abietella. Oviposition of Barbara colfaxiana and Contarinia oregonensis commences with the opening of the cone buds. The egg parasite Trichogramma sp. was found to attack the eggs of Barbara, becoming more prevalent toward the end of the oviposition period.

Unseasonably cold weather and snow occurring in late April and again in late May severely hampered this study. The young cones apparently will withstand temperatures as low as 28° F., but cold weather and snow caused sharp reductions in the survival of the eggs of Barbara colfaxiana.

Larvae of Dioryctria abietella appeared in the cones in mid-July. Some of these reached maturity and left the cones by the last week of August; however, small larvae were will present. In heavily infested cones, earlier damage by other insects was completely obliterated, and cannibalism was observed. When the cones were destroyed, the larvae abandoned them to feed on foliage and mine in the smooth bark of the tree.

Various phenological events on native plant species were observed to occur in a sequence which was related to temperature and to events in the life cycles of cone insects. Some of the events observed may be of value as indicators of the stage of development of the insects or for predicting the occurrence of certain events such as the start of insect attack. To be useful there must be a consistent relationship between the phenological event and the event for which it is to be an indicator. A number of years of observations will be required to determine which events are related consistently enough to aid in timing sampling and control operations.

A small-scale test was conducted to determine the effect of diesel oil on Douglas-fir cones, a common solvent for insecticides. The test showed that diesel oil applied at rates as low as 5 gallons per acre kills the cones. Consequently it should not be used if the spray will be applied at rates of 5 gallons or more per acre.

## INTRODUCTION

The studies described in this report are part of a continuing research project on insects which attack the cones and seeds of Douglas-fir. Previous work on this project is reported in several other reports similar to this one[1/] and the general outlines and objectives of the work are presented in a problem analysis.[2/]

The principal objectives of those studies reported here were to obtain a more complete picture of the species composition of the insect complex associated with Douglas-fir cones and to obtain information on the habits and seasonal history of those insects which are known to damage the cones. It seemed particularly important to obtain data on the time of attack of the various species. These data are being studied in relation to the local weather and phenological phenomena. Information on the basic life cycles of the insects and on the detailed timing of the various events of the life cycle will form the indispensable background for the conduct of further research and the eventual development of control practices.

The field work for this project was done in the vicinity of Orleans in Humboldt County on the Six Rivers National Forest. A field laboratory is located at the Orleans Ranger Station where some of the communication and support facilities were made available to project personnel.

The help of C. J. DeMars, who assisted in gathering and examining the cone samples, is gratefully acknowledged along with the services of the personnel of the Insect Identification and Parasite Introduction Research Branch, Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, who identified the insects collected in this study.

## COLLECTION AND REARING OF INSECTS ASSOCIATED WITH DOUGLAS-FIR CONES

### IDENTITY OF INSECTS

During the past several years considerable effort has been devoted to obtaining adult specimens and authoritative species determinations of the insects associated with the cones of Douglas-fir. This work was continued during 1960 with particular attention being directed toward

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1/ Koerber, T. W. 1960. Douglas-fir cone and seed insect research, progress report 1957-1958. U. S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., 29 pp., illus. (Proc.)

Koerber, T. W. 1962. Douglas-fir cone and seed insect research, progress report 1959. U. S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., 37 pp., illus. (Proc.)

2/ Koerber, T. W. 1960. Insects destructive to the Douglas-fir seed crop in California--a problem analysis. U. S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta. Tech. Paper 45, 36 pp., illus. (Proc.)

insects present in or on immature cones, but not present when the cones reach maturity. Seven previously unreported insect species were found and have been identified by specialists in the U. S. National Museum. Of these, three species are suspected of in some way injuring the seed crop. The remainder are parasites. (See Table 1.)

Table 1.--Previously unreported insects found in association with Douglas-fir cones of the 1960 crop

| |
|---|
| HEMIPTERA |
| *Largus cinctus californicus* (Van D.) |
| *Psallus* sp. |
| THYSANOPTERA |
| *Oxythrips* sp. |
| DIPTERA |
| *Anachaetopsis tortricis* (Coq.) |
| *Xanthophyto* n. sp. |
| HYMENOPTERA |
| *Copidosoma* sp. |
| *Platygaster* n. sp. |

*Largus cinctus californicus* (Van D.) is a large hemipteran of the family Pyrrhocoridae. The adults are 12 to 15 mm. long and are black in color with red markings along the posterior edge of the prothorax, the lateral margins of the hemelytra, and the base of the legs and antennae. Adults were commonly encountered on cone-bearing branches of Douglas-fir trees during May and June. This insect was not observed to feed on the cones. Its presence is, however, noteworthy because several other representatives of the genus are reported to damage various berry crops and cotton bolls.

*Psallus* sp. is a small mirid bug. The adults measure 2-3 mm. in length and are yellowish green in color. The nymphs and adults feed on the cones and possibly on the foliage of Douglas-fir. Nymphs were encountered on the cones from mid-April to mid-May. It appears that the adults leave the cones before the beginning of June. *Psallus seriatus* (Reut) is a common pest of cotton, causing the immature bolls to drop from the plants.

Oxythrips sp. is a typical thysanopteran. Adults are slightly over 1 mm. long; they vary in color from yellow to orange and have grey wings. Adults and nymphs alike are found in large numbers in the staminate flowers of Douglas-fir, and are also found in the developing cones in April and early May. Various species of thrips have been reported to feed on pollen, and this is the most probable feeding habit of Oxythrips sp.

Anachaetopsis tortricis (Coq.) is a tachinid fly parasitizing Barbara colfaxiana. The larva of A. tortricis develops as a solitary internal parasite of the Barbara larva. The Barbara larva is killed shortly before pupation, whereupon the parasite larva emerges through a hole in the skin of its host. The parasite usually leaves the cone to form a puparium, and the adult tachinids emerge within a few weeks after pupation.

Xanthophyto n. sp. is a tachinid parasite reared from larvae of Dioryctria abietella. The parasite larva kills the mature Dioryctria larva in late summer. The parasite pupates after leaving its host, spends the winter in the pupal stage, and emerges as an adult in early summer.

Copidosoma sp. is a polyembryonic internal parasite of Dioryctria abietella. Parasitism by this species is not evident until after the last instar larva spins its cocoon. After the host completes its cocoon it is consumed by a large number of parasite larvae. The parasite larvae pupate within the distended skin of the dead host where they spend the winter. The adults emerge in early summer. A parasitized Dioryctria larva will produce over 100 Copidosoma adults.

Adults of Platygaster n. sp. are usually found between the scales of developing Douglas-fir cones during the oviposition period of Contarinia sp. Its activities and its phylogenetic position suggest that it is a parasite of Contarinia oregonensis.

## TIME AND SEQUENCE OF EMERGENCE

Infested Douglas-fir cones were collected in the fall of 1959 and held over the winter in gallon cartons in the Orleans insectary. The approximately 6 gallons of cones included samples from four widely separated localities. When the insects emerged from the cones in the spring of 1960, daily emergence records were kept for each species of insect and each locality represented. The start of insect emergence somewhat preceded the start of observations, but since most of the insects were alive on March 28 except for Ernobius sp., emergence probably started about March 25.

Barbara colfaxiana probably began to emerge about March 25; adults continued to emerge intermittently until April 14. There was no definite peak of emergence, but the moths seemed to favor warm, dry days for emergence.

Exeristes comstockii (Cress.) emerged over a period which roughly coincided with the emergence period of its host B. colfaxiana. Another parasite of B. colfaxiana, Exochus evetriae Roh. emerged intermittently over a period from April 8 to May 4.

Adults of Megastigmus spermotrophus Wachtl began emerging on April 3. Emergence continued uninterrupted until April 14, and a few intermittently until April 26. The males preceded the females. The first females emerged on April 6, and the last male emerged on April 10.

When observations were started on March 28, emergence of Ernobius sp. was well underway. To judge by the number of dead specimens present, emergence might have started as early as March 15. Sporadic emergence continued until April 10. Figure 1 presents a graphic presentation of the foregoing data.

## LONG-TERM REARINGS FROM INDIVIDUAL CONES

Fifty insect-infested cones were collected from each of four Douglas-fir trees in September 1959. Each cone was placed in a half-pint cardboard container and held in the Orleans insectary until August 1960, when the cones were examined and a record made of the numbers of the various species of insects which had emerged. In August 1961 the cones were again examined and the insect emergence recorded. An additional sample of 40 cones was collected on April 4, 1960, from one of the same trees which supplied one of the other samples. These cones were caged and treated in the same manner as the others.

All of the cones used were infested with cone and seed insects. Dissection of samples of cones from the same trees revealed that Barbara colfaxiana, Megastigmus spermotrophus, and Contarinia sp. were the most prevalent species.

In 1960 insects emerged from 135 of the 240 cones, and in 1961 additional insects emerged from 78 of the 240 cones. Insects emerged from 37 cones which had not produced any insects previously. Thus, to date (January 1962) insects have emerged from 172 (71.7 percent) of the 240 cones.

To date 51 adults of Barbara colfaxiana have emerged from the cones, along with 59 insects known to be parasites and predators of this species. It is of particular interest to note that 64.8 percent of the B. colfaxiana delayed emergence until 1961. The proportion of the population which delayed emergence was extremely variable, ranging from 30 to 89 percent. (See Table 2.)

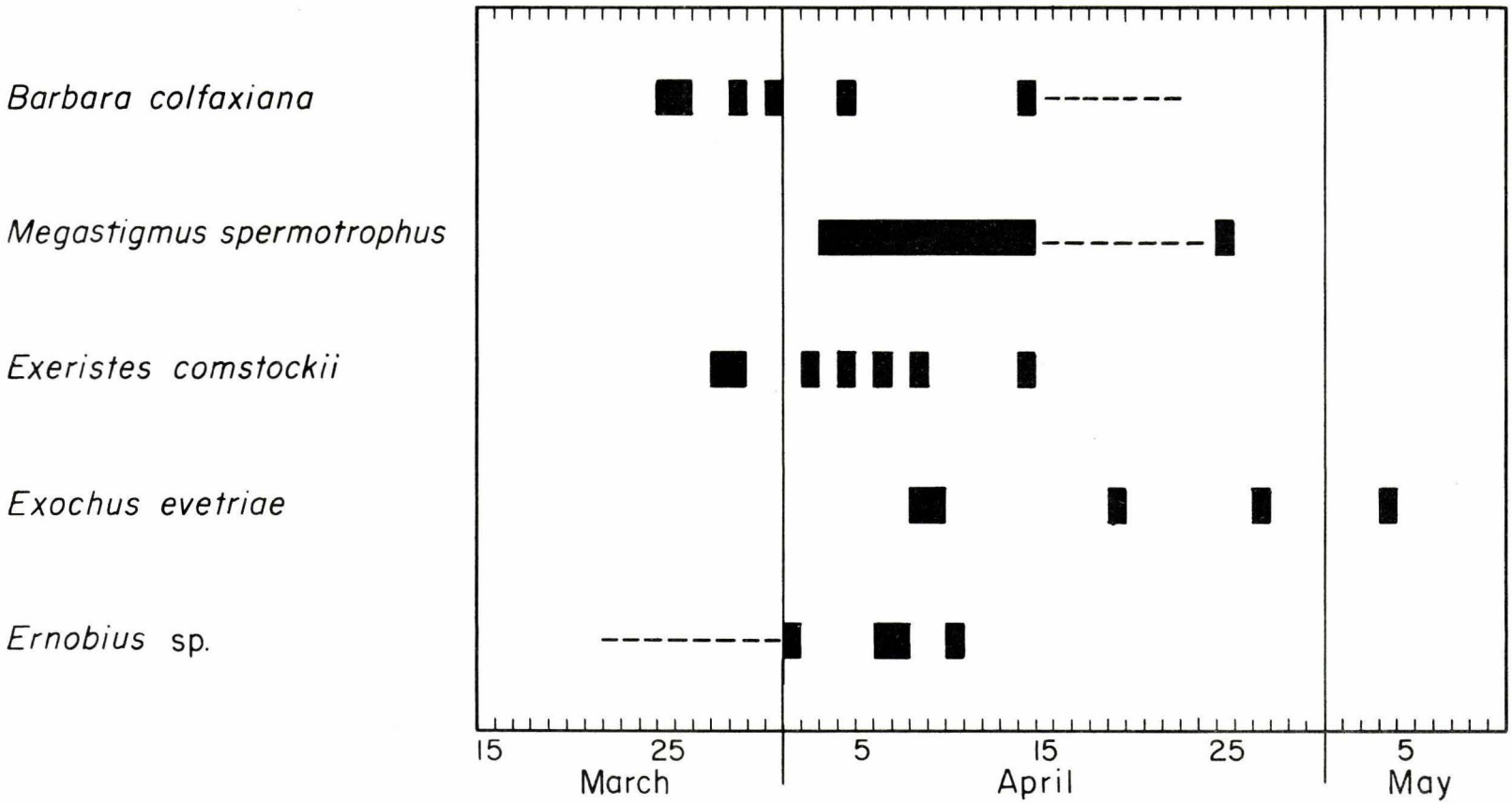


Figure 1.--The time and sequence of emergence of insects from Douglas-fir cones at Orleans, California, 1960.

Table 2.--Emergence of Barbara colfaxiana from Douglas-fir cones of the 1959 crop

| Sample | Number of cones | Emergence in 1960 | Emergence in 1961 | Total emergence | Delayed emergence |
|---|---|---|---|---|---|
| | | Number | | | Percent |
| 1 | 50 | 7 | 3 | 10 | 30.0 |
| 2 | 50 | 2 | 2 | 4 | 50.0 |
| 3 | 50 | 6 | 9 | 15 | 60.0 |
| 4 | 50 | 2 | 11 | 13 | 84.7 |
| 5 | 40 | 1 | 8 | 9 | 89.0 |
| Total | 240 | 18 | 33 | 51 | $\bar{X}$ 64.8 |

Over the same period of time, 215 specimens of Megastigmus spermotrophus emerged from the same cones. Delayed emergence was also common with this species, 80 individuals emerging in 1961. For the population as a whole, 37.2 percent emerged after two winters in the cones. Delayed emergence in individual samples ranged from 10.3 to 75.0 percent. (See Table 3.)

Table 3.--Emergence of Megastigmus spermotrophus from Douglas-fir cones of the 1959 crop

| Sample | Number of cones | Emergence in 1960 | Emergence in 1961 | Total emergence | Delayed emergence |
|---|---|---|---|---|---|
| | | Number | | | Percent |
| 1 | 50 | 35 | 4 | 39 | 10.3 |
| 2 | 50 | 17 | 5 | 22 | 22.7 |
| 3 | 50 | 67 | 23 | 90 | 25.6 |
| 4 | 50 | 8 | 24 | 32 | 75.0 |
| 5 | 40 | 8 | 24 | 32 | 75.0 |
| Total | 240 | 135 | 80 | 215 | $\bar{X}$ 37.2 |

Various parasites and predators were present in the cones. The principal species whose host relationships are known were Exochus evetriae, Exeristes comstockii, and Bracon sp., parasites of B. colfaxiana; Torymus sp., a parasite of Contarinia sp.; and Enoclerus humeralis, a general predator. While the samples available were not large enough to give reliable quantitative data, the records show that all of these species delay emergence to some extent. (See Table 4.) However, delayed emergence is not nearly as prevalent among the parasites and predators as it is in the host. While 29 parasites of B. colfaxiana emerged from the cones in 1960, only 3 emerged in 1961. The same cones yielded 18 specimens of B. colfaxiana in 1960 and 33 in 1961.

Table 4.--Emergence of parasites and predators from Douglas-fir cones of the 1959 crop

| Species | Number emerging in 1960 | Number emerging in 1961 | Total |
|---|---|---|---|
| Exochus evetriae | 11 | 1 | 12 |
| Exeristes comstockii | 17 | 1 | 18 |
| Bracon sp. | 1 | 1 | 2 |
| Torymus sp. | 18 | 3 | 21 |
| Enoclerus humeralis | 26 | 2 | 28 |

An additional sample of 50 cones of the 1959 cone crop was collected in March 1961 from the same tree which provided the samples numbered 4 and 5 on the tables. These old cones which had been on the tree for 2 full years were still infested. The sample of 50 cones yielded 5 specimens of B. colfaxiana, 3 of M. spermotrophus, 2 of E. evetriae, and 2 of E. comstockii.

The phenomenon of delayed emergence has important implications when we consider the practical aspects of insect control. Delayed emergence is evidently an adaptation which enables these insects to survive in large numbers in years of cone crop failure. Obviously this adaptation also enables the insects to survive insecticide applications. If insects continue to emerge from cones which are two, or possibly more, years old, the problem of obtaining an estimate of the insect population upon which to base the decision of whether or not to spray also becomes very complex.

The large variations in the proportion of the insect populations emerging after one winter or after two winters in the cones further complicates the situation, and leads one to speculate about the possible causes for the variation. All of the cones were held under identical conditions in the insectary. Therefore, we must look for factors affecting the insects before the cones were collected. Possibly some factor of nutrition or growing conditions during the summer controls the proportion of delayed emergences. Perhaps we are dealing with two physiological strains, one of which has an extended diapause period. The data indicate that cones which contain a high proportion of late emerging Barbara also contain a high proportion of late emerging Megastigmus, and this relationship seems a bit too constant to occur by chance. Perhaps the same underlying cause controls the delayed emergence of both species.

The principal parasites of cone insects also exhibit the adaptation of delayed emergence but to a lesser extent than their hosts. Therefore, in a year when the cone crop failed, there would be a proportionately greater reduction of the parasite population such that in the following year the surviving host population would be subjected to less parasitism than would otherwise be the case.

One would expect considerable mortality among insects which delayed emergence for 2 years under field conditions. The cone sample collected in March of 1961 yielded 5 specimens of B. colfaxiana as compared with 8 and 11 specimens from cones collected earlier from the same trees. This might indicate about 50 percent mortality in the field. Better mortality information will be obtained when the cones are dissected.

## LABORATORY REARINGS UNDER CONTROLLED CONDITIONS

Data on the time required for the pupae of B. colfaxiana to develop into adults at various temperatures is needed to form a basis for the use of weather records to predict emergence dates in the field. The insect also has a winter diapause which must be broken by means of cold treatments before development will proceed.

Cocoons of B. colfaxiana were obtained by dissecting Douglas-fir cones of the 1960 cone crop. The cones were held under refrigeration from September 15 to February 6, 1961. The temperature in the refrigerator fluctuated between 32 and 38° F., while the relative humidity fluctuated between 60 and 98 percent. The fluctuations followed a cyclic pattern, about 1 hour being required for a complete cycle. On February 6 the cocoons were transferred to an incubator having a constant temperature of 72° F. and a constant relative humidity of 95 percent.

At the time the cocoons were transferred, some of them were opened so the progress of development could be observed. About half of the cocoons contained prepupae of Exeristes comstockii rather than pupae of Barbara colfaxiana. Within a few days the B. colfaxiana pupae began to show the colors and wing pattern of the adult. The first adult B. colfaxiana emerged on February 17, after 11 days in the incubator. Emergence continued for 9 days.

The prepupae of Exeristes comstockii almost immediately transformed to pupae and in turn to adults. The first pupae were noted after 2 days of incubation. The first adult male emerged after 9 days of incubation and the first adult female after 11 days of incubation. It is interesting to note that the emergence of the first female parasite coincided with the emergence of the first adult host.

The 58 cocoons in the experiment yielded 17 specimens of B. colfaxiana and 20 of E. comstockii. The remaining cocoons were opened and found to contain dead pupae and prepupae of B. colfaxiana and E. comstockii respectively. These individuals were probably injured when the cocoons were removed from the cones or were diapausing and died from prolonged incubation.

## STUDIES ON THE SEASONAL HISTORY OF CONE AND SEED INSECTS

### PERIODIC SAMPLING

Previous years' observations indicated that Douglas-fir cone and seed insects attack the cones in early spring. Systematic observations to determine more exactly the time of attack were started in 1959 and were continued in 1960.

### EXPERIMENTAL AREAS AND CONDITIONS

Observations were scheduled at Orleans and three nearby locations at which trees were easily climbable, readily accessible by road, and on the basis of bud counts, promised to have good cone crops. Extremely unfavorable weather conditions, however, prevented studies at two of the locations. The cone crop at the remaining locations was rather scanty, necessitating a reduction in sampling intensity. Cones were collected from one tree at each of these locations.

One of the trees is located in a small ravine on the north boundary of the Orleans ranger station (T11N, R6E, sec. 31, Humboldt Co.). The area was formerly a hydraulic mine and at present is a small flat at 600 feet elevation with thin, stony soil. The flat is vegetated mainly with manzanita, ponderosa pine, Douglas-fir, red alder, willow, and madrone. The tree from which the cone samples were obtained is an open-grown specimen about 40 feet tall and 15 inches DBH.

The second location is a southeast-facing slope above the north fork of Red Cap Creek, about 8 miles south of Orleans at 2,200 feet elevation (T10N, R6E, sec. 32). The vegetation in this area consists of small Douglas-fir trees scattered over a slope covered mainly with various brush species. The tree from which the samples were obtained is an open-grown individual about 60 feet tall and 12 inches DBH.

The weather in the study areas was abnormally warm during March. The early warm weather was followed by severe cold spells in April and May which virtually destroyed the Douglas-fir cone crop above 3,000 feet. Data gathered by the U. S. Weather Bureau at Orleans show that maximum temperatures reached or exceeded 75° F. on 10 days during the last half of March and on 5 days during the first half of April; but a cold storm during mid-April sent temperatures to 33° F. (Fig. 2). A thermograph record obtained at the Red Cap location at 2,200 feet registered a low temperature of 28° F. The cones at the Red Cap location survived the 28 degree weather. However, cone mortality was virtually complete above the 3,000 foot level and extended in some areas to the 2,500 foot level. Cones above the 4,000 foot level, which had not emerged from the buds, were not damaged.

Near normal temperatures prevailed during the first half of May. The cones at high elevations which had survived the cold weather emerged from their buds. Record low temperatures then occurred from May 20 to 24. Snow fell at the 3,500 foot level; a thermograph at 5,000 foot elevation on Grouse Mountain (T5N, R4E, sec. 23, Siskiyou County) registered a minimum temperature of 26° F. By this time all the cone buds which had survived the April frost were open, and again cone mortality was complete.

Rainfall in the north coast area of California was near normal during the spring of 1960. The departures from normal rainfall which did occur are not considered large enough to affect the behavior of the insects. (See Table 5.)

Table 5.--Departures of 1960 temperature and rainfall from long-term means for the north coast area of California 1/

| Month | Average temp. at Orleans | Departure from mean temp. | Total rainfall at Orleans | Departure from mean rainfall |
|---|---|---|---|---|
| | Degrees F. | Degrees F. | Inches | Inches |
| March | 52.9 | + 2.6 | 10.51 | + 2.34 |
| April | 54.4 | - 0.5 | 2.67 | - .85 |
| May | 57.9 | - 2.0 | 6.53 | + 1.78 |
| June | 70.9 | + 4.5 | 0.00 | - .82 |

1/ U. S. Weather Bureau data.

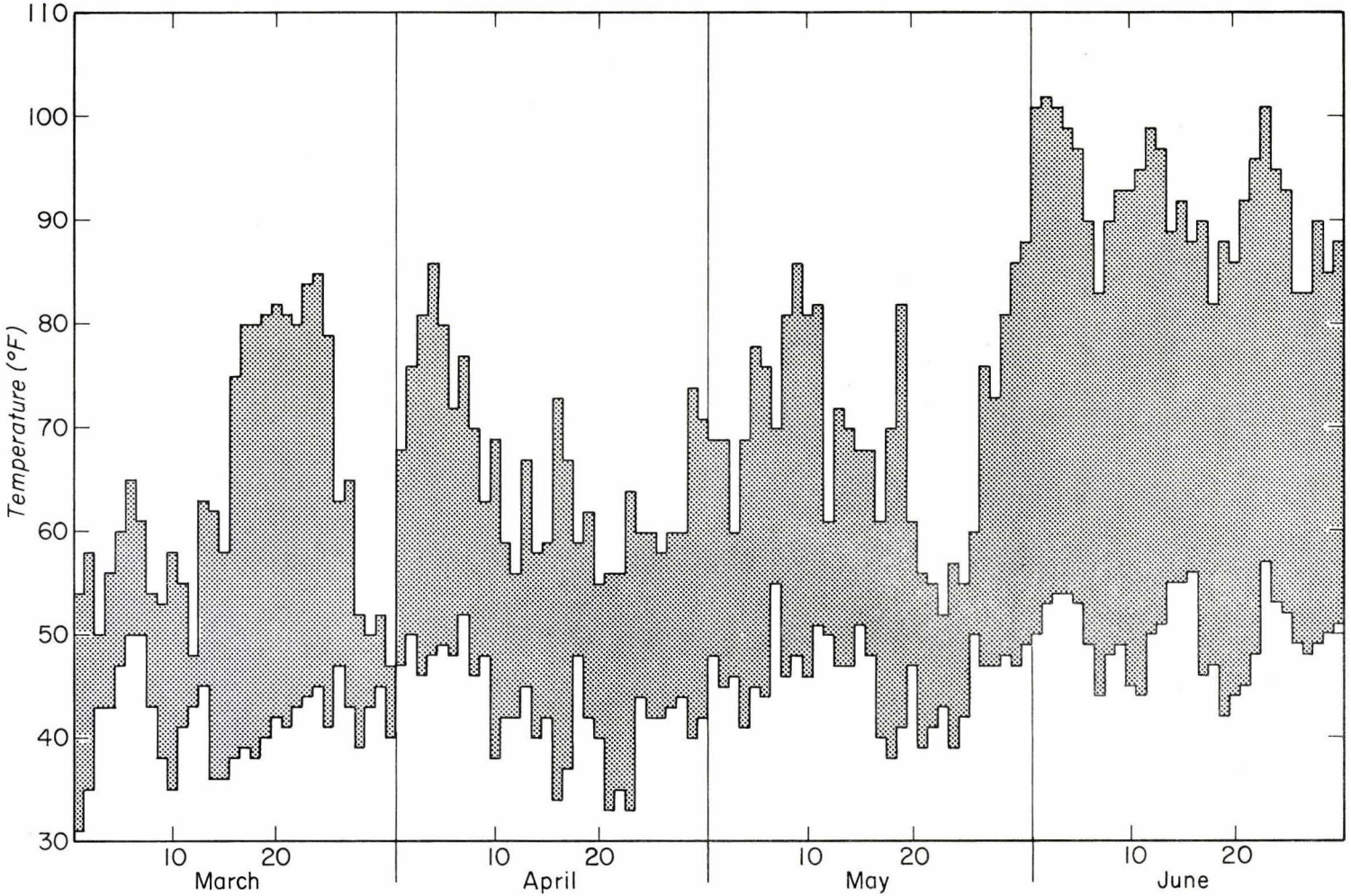


Figure 2.--Daily temperature ranges as recorded by the U. S. Weather Bureau at Orleans, California, from March 1 to June 30, 1960.

On the basis of the foregoing observations it appears that the new cones of Douglas-fir will tolerate temperatures as low as 28° F. for short periods, but will not survive if the temperature drops to 26° F. The effect of the duration of the cold period may also be important but cannot be judged from the data on hand.

In this instance the low temperatures acted indirectly on the insect population by destroying the food supply. Thus those species which are host specific produced no progeny in 1960 in the area where the cones were destroyed. Only the portion of the population which delayed emergence until 1961 could survive in the absence of cones.

## INSECTS STUDIED

Samples of 10 cones each were collected at intervals from each of the 2 trees studied from early April through June. The cones were dissected and a record was made of the numbers and stage of development of the insects found.

### Barbara colfaxiana

During this period Barbara colfaxiana was present in the egg and larval stage. At Orleans the first eggs were found on April 2, when 4 eggs were noted on a sample of 10 cones. More eggs were found on samples collected on April 4 and April 7. The first larvae were found on April 12, when a sample of 10 cones yielded 3 larvae and 6 eggs. Eggs continued to be found on the cones until May 12. The larval population reached its highest level on April 29, when 7 larvae were found on 10 cones. After this time, the population dropped off; in spite of continuing oviposition succeeding samples showed populations of only 3 to 5 larvae in 10 cones.

At the Red Cap sampling locations the first sample, collected on April 7, showed an average of 2.7 eggs per cone. The number of eggs per cone increased sharply to 5.9 in the next sample, April 13. At this time the number of eggs on individual cones ranged from 0 to 13 (Fig. 3). By May 2 the egg population had again dropped to 2.7 eggs per cone, but larvae were not yet present. The first larvae were found on May 9, when the cones had an average of 0.9 larvae and 3.3 eggs per cone. The larval population more than doubled between May 9 and May 19, when an average of two larvae per cone were found. Over the same period the number of eggs declined to 1.8 eggs per cone. The last eggs were found on May 28, when the sample still averaged 0.9 eggs per cone. The larval population showed a net loss over the same period and now stood at 1.3 larvae per cone. The last sample, collected on June 21, showed an average of 2.8 larvae per cone.

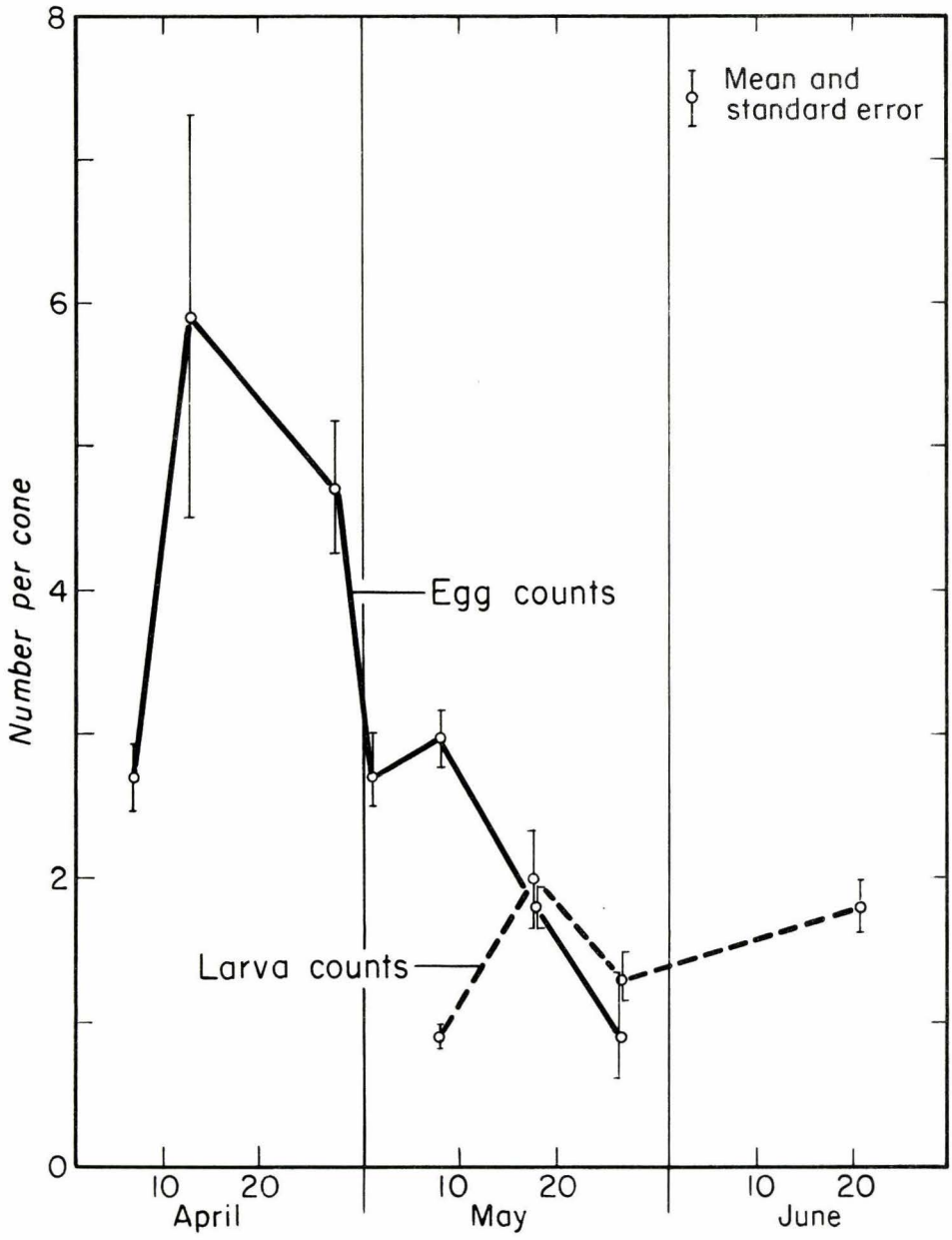


Figure 3.--Numbers of eggs and larvae of Barbara colfaxiana in Douglas-fir cones at Red Cap.

In previous years it had been noted that B. colfaxiana egg survival appeared to be higher at the beginning than at the end of the oviposition period. To check this empirical observation, all of the eggs found on the cones collected at the Red Cap location were held in the laboratory to determine their viability. The eggs are deposited on cone bracts, and when bracts with eggs were found they were plucked from the cone and placed in individual gelatin capsules for observation. It was found that the survival of the eggs did indeed decline in the course of the oviposition period. All of the eggs in the first sample collected produced larvae, but only 60 percent of the eggs in the last sample were viable. (See Table 6.)

Table 6.--Viability of eggs of Barbara colfaxiana in relation to the date of collection

| Date of collection | Eggs collected | Larvae produced | Parasites produced | Unhatched eggs remaining |
|---|---|---|---|---|
| | Number | | | |
| April 7 | 27 | 27 | 0 | 0 |
| April 13 | 59 | 57 | 0 | 2 |
| April 28 | 47 | 41 | 1 | 5 |
| May 2 | 27 | 18 | 4 | 5 |
| May 9 | 33 | 27 | 2 | 4 |
| May 19 | 18 | 15 | 3 | 0 |
| May 27 | 15 | 9 | 6 | 0 |

The most prominent factor affecting egg viability was parasitism by Trichogramma sp. Trichogramma accounted for all of the rather considerable egg mortality encountered in the last two samples, but other unidentified causes accounted for over half of the egg mortality in the earlier samples (Fig. 4).

From the foregoing data we see that oviposition by Barbara colfaxiana started somewhat before April 1 at Orleans, and perhaps 10 days or 2 weeks later at a nearby location 2,000 feet higher. The first larvae were found at Orleans on April 12, but larvae did not appear until almost a month later at the higher elevation site. Larval populations at both locations built up rapidly at first and then declined, although oviposition continued for at least 2 and possibly 3 weeks after the first larvae appeared. At both locations the larval populations after the end of the oviposition period were far lower than the peak egg populations. It appears that both weather conditions and parasites are responsible for the final level of the population.

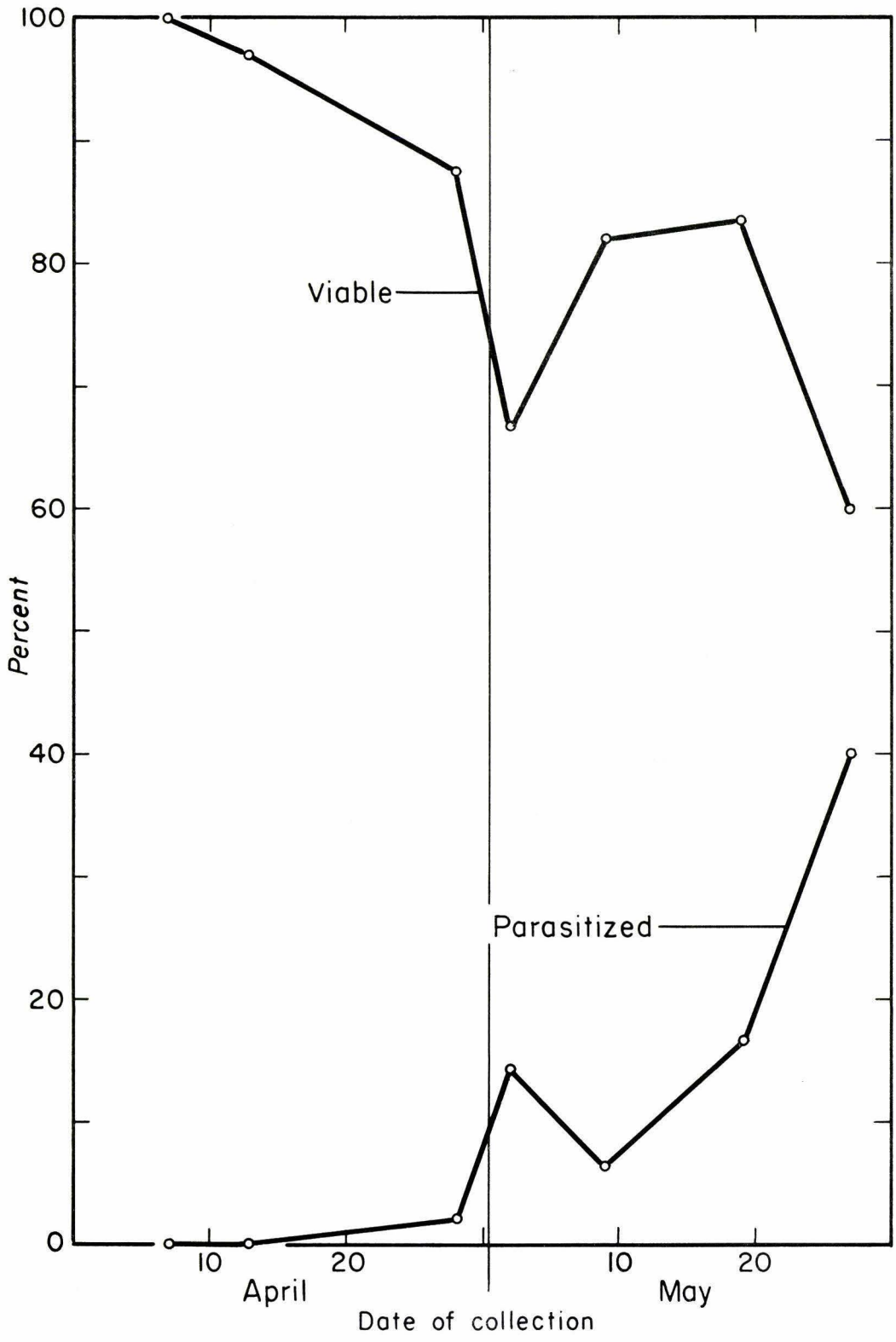


Figure 4.--Viability and parasitism of eggs of Barbara colfaxiana in relation to the date of collection.

The effect of the weather conditions and parasites is clearly illustrated by the data from Red Cap. There a period of cold weather (April 16-23) sent temperatures to a low of 28°. During and immediately after this period the average number of eggs per cone dropped from 5.9 to 2.7.

Laboratory tests showed that 87.5 percent of the eggs were viable, but no larvae appeared on the cones. This suggests that low temperatures may have killed the developing larvae or the rain and snow, which accompanied the low temperature, may have dislodged the eggs from the cones.

Trichogramma sp. was found to parasitize the eggs of Barbara colfaxiana and was particularly abundant at the end of the oviposition period. Parasitism by Trichogramma is probably responsible for the anomalous situation which prevailed during the last half of May. During this time the number of eggs on the cones declined but the larval population also declined. If the eggs were producing larvae, the larval population should have increased as the number of eggs declined. However, a combination of egg parasites and predators attacking the larvae would be expected to produce the situation which prevailed.

## Dioryctria abietella

Dioryctria abietella (D. & S.) was conspicuous by its absence in the spring cone samples. In fact, none of the cones collected through June 21 harbored a single Dioryctria larva. In mid-July cone samples were collected from the same trees and from others at 12 locations within 10 miles of Orleans. Every one of the trees sampled had cones infested by D. abietella; the average being 0.63 Dioryctria larvae per cone. The number ranged from 1.3 larvae per cone at Orleans to 0.10 larvae per cone at Red Cap. Some of the larvae were in advanced instars, indicating that the attack on the cones was well advanced.

Samples of cones were collected from the same trees during the last week of August. By this time some of the larvae had matured and left the cones, so the total number of larvae that had been involved could not be determined. However, all of the cone samples showed damage from Dioryctria feeding in much the same proportion as the infestations in the July samples. In the most lightly damaged sample only 1 cone out of 15 was damaged; but some cones were so heavily damaged that the larvae abandoned them and fed on the bark and foliage of the tree. As many as four large larvae were found in a single cone and early instar larvae were still present in some.

When feeding on foliage, the larvae feed from a shelter constructed by webbing together needles and twigs. Some of the largest shelters observed were over 2 inches long. These consisted of a prominent greenish mass of needles, needle fragments, and frass, sheltering single, nearly mature larva, and thin white webbing extending outward among the needles where the larva had been feeding.

When feeding on bark, the larvae constructed an irregular linear ovate mine in the smooth, grey bark of the upper bole of the tree. The entry point was usually at the point where a branch joined the bole or at a roughened or damaged place on the bark. The larvae appear to feed on both the bark and cambium of the tree but do not score the wood. The interior of the mine is kept clean, and the frass and bits of excavated bark are webbed together to form a compact reddish-brown mass covering the entrance to the mine.

The last collections were made on September 3. At this time pupae in cocoons and mature larvae in hibernacula were found in some cones. The cocoons are oblong in shape, 15 to 20 mm. long and 5 mm. in diameter. The hibernacula are circular, about 10 mm. in diameter, and dorsoventrally flattened so that they are about 4 mm. high. Both cocoons and hibernacula are normally covered with a layer of frass, soil particles, or other debris. Prepupal larvae in cocoons lie in an extended position, while larvae in hibernacula lie in a laterally curled, almost circular position.

These observations point up two peculiarities in the life cycle of D. abietella: (1) the cones are not attacked until July, by which time they are nearly full grown; and (2) the insect appears to pass the winter in both the egg and larval stages. The site of egg deposition is unknown but is presumed to be somewhere other than on the cones. Adults emerging in the fall could not oviposit on the cones, which do not appear until the following spring. Those individuals which overwinter as larvae presumably pupate and become adults the following spring. These adults could deposit eggs on the cones, but none of the eggs found on the cones during the spring produced Dioryctria larvae.

D. abietella is obviously a very versatile insect. It seems to prefer to feed on cones and has been reported to feed on the cones of many species of conifers. When the preferred food supply runs short, however, it will turn to foliage and bark for food.

## Contarinia oregonensis

At Orleans the eggs of Contarinia oregonensis were present in all of the cones collected from April 2 to April 12. Oviposition started before the first cone collections, probably between March 20 and 25. In the first cone sample the number of Contarinia eggs ranged from 13 to well over 50 per cone. In later samples uncountable masses of Contarinia eggs were found between the cone scales; the cones were estimated to hold at least several hundred eggs each. At Red Cap Contarinia eggs were present in the cones collected on April 7 and April 13. On April 13 the maximum number of eggs was 51, and only 3 of the 10 cones were infested.

The oviposition habits of Contarinia sp. are well documented and require no elaboration here except to note that the insects attacked promptly after the cone buds opened, and that at Orleans tremendous numbers of eggs were deposited in a short time.

## Other Species

A species of thrips, thus far identified only as Oxythrips sp., was found in the cones in early spring. Only a few specimens were encountered in the cones collected at Red Cap, but the species was fairly prevalent in the cones at Orleans. Three adults were found in the first sample of 10 cones collected on April 2. By April 7 the count rose to 7 thrips, again all adults, in 10 cones. The adults abruptly disappeared, being replaced by nymphs. On April 12 there were 16 nymphs in a 10-cone sample. On April 28 only one adult was found, and thrips were not encountered for the remainder of the summer. No damage attributable to thrips was noted, and it is possible that they were feeding on the pollen lodged between the cone scales. The staminate flowers harbored large numbers of thrips, but no counts were made.

A bug, Psallus sp., was also encountered in considerable numbers at Orleans, but sparingly at Red Cap. Psallus nymphs were found on cones at Orleans on April 28, and the first adult was encountered on May 12. The last specimen was found on May 19. The peak population found in the cone samples was 3 nymphs in a sample of 10 cones on April 5. Psallus nymphs have been observed to feed upon the cones, but they have also been collected on Douglas-fir foliage so they may not be restricted to feeding on cones.

Although these previously unreported insects were regularly encountered in the cones, no damage which could be attributed to their activities was detected. The feeding habits of both species are such that the damage would be difficult to detect and recognize, so the fact that no damage was found is not significant. These species should be kept under close scrutiny until their role is positively determined.

## CONE BAGGING

A cone bagging experiment similar to those conducted in 1958 and 1959 was attempted in 1960. Cone-bearing branches at Orleans and two other locations at higher elevations were covered with bags made of 25-mesh dacron netting. The unseasonably cold weather referred to earlier destroyed the cones at the two high elevations, leaving only those at Orleans.

In late summer the larvae of Dioryctria abietella entered the bags covering the cones. The damage they caused was so severe as to preclude any estimate of the injury due to other species of cone and seed insects, and the data we hoped to obtain on the time of attack of the various species were lost. However, the cones were examined to determine the severity of the Dioryctria infestation.

The total number of cones bagged was 112. From these cones and the bags enclosing them a total of 198 larvae, pupae, and adults of D. abietella was obtained. All of the seed within the cones was eaten. Pupae of Barbara colfaxiana were destroyed and many instances of cannibalism were observed.

The fact that bagged cones were heavily attacked regardless of whether the bags were present or absent strongly suggests that the small larvae seek out the cones, and are able to pass through the openings in the 25-mesh netting to get to the cones. After a period of growth they were no longer able to leave the bag, and parasites and predators were unable to enter the bag. As a result the larvae survived to the limit of their food supply, where starvation and cannibalism finally limited the number of survivors.

## PHENOLOGICAL RELATIONSHIPS OF CONE AND SEED INSECTS

Over the past several years it has been noted that the attack periods of the insects are closely correlated with the developmental stages of the cones. It has further been established that the various species of insects emerge in a set sequence, and that the native plants in the Orleans area exhibit a sequence of phenological events. This is particularly noticeable in the order in which various plant species bloom or start vegetative growth in the spring. These observations led to studies aimed at finding some readily observable phenological events in common native plants which coincide with, or precede the attack periods of the insects attacking Douglas-fir cones.

### METHODS AND OBSERVATIONS

It was originally intended that tagged plants would be observed at intervals of about 1 week at the three locations where cone bagging experiments were in progress. A thermograph record was to be made at each location, and data on the emergence and attack periods of the insects gathered.

When frost destroyed the cone crop at two locations, observations on the attack periods of the insects were limited to the one remaining. This was at Orleans where complete information was obtained on insect emergence and attack data, phenological events among plants, and weather data suitable for calculating developmental units. Observations were made on four tagged individuals of each of 12 species of trees and shrubs:

| | |
|---|---|
| Douglas-fir | Pseudotsuga menziesii (Mirb.) Franco |
| Ponderosa pine | Pinus ponderosa Laws. |
| Pacific madrone | Arbutus menziesii Pursh |

| | |
|---|---|
| Pacific dogwood | Cornus nuttallii Aud. |
| California-laurel | Umbellularia californica (Hook. & Arn.) Nutt. |
| California black oak | Quercus kelloggii Newb. |
| Tanoak | Lithocarpus densiflorus (Hook. & Arn.) Rehd. |
| Golden chinkapin | Castanopsis chrysophylla (Dougl.) A.DC. |
| Red alder | Alnus rubra Bong. |
| California blackberry | Rubus vitifolius C. & S. |
| Common chokecherry | Prunus virginiana L. |
| Poison oak | Rhus diversiloba T. & G. |

The thermograph record was used to calculate cumulative developmental units expressed as degree days. (Formula $\frac{\text{Maximum Temperature} + \text{Minimum Temperature}}{2} - 45$). The emergence and attack data mentioned earlier in this report were used to determine the relationships between plant phenological events and important details of the life cycle and habits of the insects. A chart showing the phenological events which may be useful is presented in Figure 5.

## DISCUSSION

Three of the plants under observation were of little use as phenological indicators. Pacific dogwood showed wide variations in the start of both flowering and vegetative growth, while flowering and vegetative growth of tanoak and golden chinkapin started too late to be used as indicators.

The opening of the cone buds and the start of pollen flight of Douglas-fir mark the start of oviposition by both Barbara colfaxiana and Contarinia sp. Nearly all the pollen was shed before emergence of Megastigmus spermotrophus began. There was little variation from tree to tree in the time the floral buds opened. Conversely the opening of the vegetative buds was quite variable. A period of several weeks elapsed between the time the first vegetative buds opened until the last were open.

Figure 5.--Phenological events of possible use in predicting events in the life cycles of Douglas-fir cone and seed insects

| Plants | Insects | | | | |
|---|---|---|---|---|---|
| | Barbara colfaxiana | Dioryctria abietella | Megastigmus spermotrophus | Contarinia sp. | Comments |
| Douglas-fir | Cone buds and staminate flowers open at start of the oviposition period | | Emergence starts just prior to end of pollen flight | Pollen flight period coincides with oviposition period. | Much local variation in start of vegetative growth |
| Ponderosa pine | | Pollen flight starts about 40 degree days before emergence of adults | | Contarinia galls are easily found by end of pollen flight | |
| Pacific madrone | Flowers during entire oviposition period | Vegetative growth starts about 110 degree days before adult emergence | | | |
| California-laurel | Begins flowering before start of oviposition | | | Begins flowering before start of oviposition | Found only at low elevations |

Figure 5.--Cont.

| Plants | Insects | | | | |
|---|---|---|---|---|---|
| | Barbara colfaxiana | Dioryctria abietella | Megastigmus spermotrophus | Contarinia sp. | Comments |
| California black oak | Vegetative growth starts about 20 degree days before first larvae | | Vegetative growth starts in middle of adult emergence period | | Little variation between individuals in time growth starts |
| Red alder | Vegetative growth starts before start of oviposition | | | Vegetative growth starts before start of oviposition | Limited to wet areas |
| California blackberry | Vegetative growth starts before start of oviposition | Floral buds appear shortly after start of adult emergence | | Vegetative growth starts before start of oviposition | Found only at low elevations |
| Common chokecherry | Flowering starts before start of oviposition period | | Petal fall coincides with peak of adult emergence | Start of petal fall and vegetative growth mark end of oviposition period | Relatively rare species |
| Poison oak | Vegetative growth starts before start of oviposition period | Flowering starts about 110 degree days before adult emergence | | Vegetative growth starts before start of oviposition | Flowers are inconspicuous |

The opening of the staminate buds and the start of shoot elongation of ponderosa pine started in early April, but these events are not conspicuous enough to be good indicators. However, the start of pollen flight and the start of needle growth occurred just shortly before the start of emergence of Dioryctria abietella. Expressed in developmental units the interval between the start of pollen flight and the first Dioryctria emergence was 40 degree days. Ponderosa pine continued to shed pollen for about 14 calendar days, 290 degree days, and at the end of the ponderosa pine pollen flight period the galls of Contarinia sp. could be easily detected in the Douglas-fir cones.

The first blossoms of madrone appeared at or shortly before the time when oviposition by Barbara and Contarinia started. Madrone continued flowering through the entire oviposition period of Barbara, but the end of the flowering period was rather indistinct. Vegetative growth of madrone started about 240-250 degree days after the start of flowering, and about 110 degree days before the start of Dioryctria emergence.

California-laurel began flowering well before the start of observations and also before the start of the attack periods of all the insects. This event may be of value for predicting the start of insect attack.

Vegetative growth of California black oak started after the beginning of insect attack, but about 20 degree days before the first Barbara larvae were found in the Douglas-fir cones. The start of vegetative growth on black oak also coincided with the peak emergence of Megastigmus. This phenological event was remarkable in that nearly all the vegetative buds on all the black oaks at Orleans opened on the same day.

Vegetative growth of red alder started before the oviposition period of any of the insects. Since this was also earlier than the start of observations the exact time is uncertain. The start of vegetative growth of red alder is, however, another indicator of possible value in predicting the start of insect attack.

The new shoots of California blackberry begin growing before the start of oviposition by Barbara and Contarinia. The floral buds appear on the bushes shortly after the start of Dioryctria emergence. Thus the start of vegetative growth might be a useful indicator for the oviposition periods of Barbara and Contarinia. The appearance of the floral buds, although somewhat variable, might be taken to indicate that Dioryctria oviposition is occurring.

The flowering of western chokecherry is one of the most conspicuous phenological events observed. The leafless trees fairly burst into bloom shortly before the oviposition periods of Barbara and Contarinia. The bloom period comes to an abrupt end when the petals fall from the trees.

The petal fall coincided with the peak emergence of Megastigmus. The start of petal fall and also the start of vegetative growth occurred at the end of the Contarinia oviposition period.

Poison oak is another plant which begins vegetative growth before any of the insects attack. The new leaves are reddish when they first appear but soon turn green. The flowers of poison oak first appear about 110 degree days before the start of emergence of Dioryctria adults.

To summarize, Douglas-fir, madrone, California laurel, California black oak, red alder, California blackberry, western chokecherry, and poison oak all provide phenological indicators of possible value in predicting events in the life cycle of B. colfaxiana.

Similarly ponderosa pine, madrone, California blackberry, and poison oak show phenological phenomena which may be useful in predicting the emergence of D. abietella.

Important events in the life cycle of M. spermotrophus coincide with or may be predicted by phenological events on Douglas-fir, California black oak, and western chokecherry.

Various phenological events on Douglas-fir, ponderosa pine, California laurel, red alder, California blackberry, western chokecherry, and poison oak are of possible value as indicators of various stages of development of Contarinia sp.

Some of the species of plants observed have qualities which may restrict their use as phenological indicators. California laurel, red alder, and common chokecherry are usually found only in wet areas. Blackberry and laurel do not occur at higher elevations. Common chokecherry, while widely distributed, is a comparatively rare species. The toxic properties of poison oak may discourage some individuals from examining it closely enough to detect the inconspicuous flowers.

It should be borne in mind that the data presented here are the results of the observations of one season at a single location. There is no way of knowing if the relationships reported are consistent from year to year and from one area to another. Further studies of these plants may be expected to show that some of the relationships observed in 1960 do not occur every year. Observations of the same species of plants and insects in other parts of the state can be expected to show that various local races or strains do not follow the same pattern observed at Orleans. However, there is reason to hope that at least a few of the relationships observed at Orleans will hold true from year to year and will at least be much the same over the range of Douglas-fir. These consistent relationships, once established and identified, can then serve as valuable aids in timing sampling and control operations.

## TOXICITY OF DIESEL OIL TO YOUNG DOUGLAS-FIR CONES

An experiment was conducted to determine the effect of diesel oil applied at various dosages to young Douglas-fir cones. Four cone-bearing branches on each of three trees at Orleans were sprayed with diesel oil at rates intended to approximate dosages of 1, 5, 10, and 20 gallons per acre. The oil was applied on April 13 as a fine spray from the nozzle of a 2-gallon pressure tank sprayer. The amount applied was estimated by comparing the deposit collected on oil-sensitive cards attached to the branches with that on similar cards previously sprayed at known rates in the spray chamber designed by Lyon and Bushing.3/ Two branches on each tree served as unsprayed checks.

All of the cones receiving dosages of oil equivalent to 5 gallons or more per acre subsequently died. Survival of the cones receiving the equivalent of 1 gallon of diesel oil per acre was 68.4 percent. Survival of the unsprayed checks was 57.5 percent. (See Table 5).

All the cones which were sprayed at the equivalent of 10 and 20 gallons per acre died within 2 or 3 weeks. Most of the mortality from the lower dosages also occurred shortly after treatment, but two cones which received the 5 gallon dosage and two which received 1 gallon died between May 27 and June 15. This delayed cone mortality along with some foliage burning on the branches receiving the 20 gallon per acre treatment seems to be associated with the high temperatures which occurred during the first week of June.

The necessity for using a reference standard for comparison leaves something to be desired in the way of accuracy in measuring the amount of oil actually applied to the cones. However, it is clear that diesel oil applied to young Douglas-fir cones at relatively low dosages will kill them. Therefore, diesel oil should not be used in insecticide formulations sprayed on Douglas-fir cones if the rate of application will approach or exceed 5 gallons per acre.

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3/ Lyon, R. L. and R. W. Bushing. 1961. The construction and performance of a portable precision spray chamber. Canadian Entomologist 93(6): 785-794. (Illus.)

Table 5.--Numbers of Douglas-fir cones surviving in diesel-oil spray tests, Orleans, 1960. Toxicity of diesel oil to young Douglas-fir cones, Orleans, 1960.

| Replicate | Treatment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 gal./acre | | 5 gal./acre | | 10 gal./acre | | 20 gal./acre | | Check | |
| | Sprayed | Survived | Sprayed | Survived | Sprayed | Survived | Sprayed | Survived | Number | Survived |
| 1 | 6 | 0 | 6 | 0 | 12 | 0 | 5 | 0 | 12 | 1 |
| 2 | 8 | 8 | 9 | 0 | 5 | 0 | 10 | 0 | 9 | 9 |
| 3 | 5 | 5 | 4 | 0 | 4 | 0 | 7 | 0 | 12 | 9 |
| Total | 19 | 13 | 19 | 0 | 21 | 0 | 22 | 0 | 33 | 19 |